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Report SIT-DL-71-1502

January 1971

EVALUATION OF NDCC AND MUD AND SNOW TIRES IN SOFT SOIL

Conduct of Preliminary Tests and Results

by

L. I. Leviticus

prepared for the
United States Army Tank-Autmotive Command
under
Contract DAAE07-69-C-0356

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ABSTRACT

This report describes the procedure and discusses the test results for a series of preliminary tests conducted in sand to compare a 7.00-16 NDCC tire with a 7.00-16 commercial mud and snow tire. There appeared to be no difference in the drawbar pull developed by the two tires. A slight difference in efficiency may well lie within the natural scatter of the experimental results. Recommendations for further research for different soil conditions and tire types are made.

Keywords

Tires
Snow - Mud Tires
Military Tires
Drawbar Pull
Efficiency

CONTENTS

LIST OF FIGURES

LIST OF TABLES

I. Aim of Investigation

To conduct a limited comparison between the off-road traction performance characteristics of a standard military tire and a standard commercial mud and snow tire. From the results of this program to suggest whether further investigations are warranted.

II. Scope

A. Two tires were tested:

a) Standard military 7.00-16 tire with non-directional, cross country (NDCC) tread.

b) 7.00-16 Uniroyal mud and snow tire: Fleetmaster - Deep Lug - 6 ply.

B. Soil

One soil type at one soil condition was tested. The soil was a beach sand. The soil condition was soft - see Table 1.

III. Test Program

Static and dynamic properties were investigated for both tires:

A. Static Tests

Load versus deflection tests were run for both tires at two inflation pressures. These tests were run on a rigid wooden surface and "footprints" of the tire were made in order to calculate an approximate contact area. Loads were increased from 600 to 900 lb in 100 lb increments.

From the data, load deflection, area deflection and nominal ground pressure-deflection curves were drawn.

B. Dynamic Tests

Both wheels were tested under a dead weight load of 620 lb at a constant velocity and at two inflation pressures.

The slip conditions were varied from a towed-free rolling condition to a driven condition. The highest slip condition was determined by the stable operation of the test rig. Each test was run under constant slip conditions and data were taken from the oscillograph.

Drawbar pull and torque were measured by means of LVDT-type transducers; wheel velocity was measured with a DC tachometer; sinkage was measured with a 10 turn potentiometer; and the carriage velocity was measured by dividing the number of distance blips, generated by a microswitch on the carriage track, by the number of time blips generated by a second timer.

C. Soil Processing

The soil was processed after each test with a gyrotiller, which reaches a depth of about 16". On the tiller frame a scraper blade has been mounted so that a uniform, smooth surface can be obtained. All tests were run after a single gyrotiller pass without any compacting.

IV. Test Results

A. Soil Tests

The soil conditions are shown in Table 1. Both WES cone penetrometer and Bevameter readings were taken. The cone index gradient was given for 3 depths in order to show the variation of strength with depth.

Cone penetration measurements after the wheel passage were measured in the bottom of the rut and on the side of the rut (see Figure 1). No difference was found between the influence of the jeep wheel and that of the snow tire.

B. Static Tire Tests

Tables IIa, IIb, IIc and IId show the influence of wheel load and internal air pressure on, respectively, the nominal contact area, the nominal ground pressure and the tire deflection.

The nominal contact area was calculated from the product of the width and the length of the contact prints made by lowering the inked wheel onto a paper. The nominal pressure was calculated by dividing the static load by the nominal contact area.

Figure 2 shows that the deflection of the snow tire was greater than that of the jeep wheel at both pressure levels. This is also seen in the plots of Figures 3 and 4 of the nominal contact area and the contact pressure versus the deflection. The explanation for this lies partly in the fact that the dimensions as well as the profiles of the two tires differ. The cross-section of the NDCC tire is roughly circular, whereas that of the mud and snow tire is nearly flat at the contact area in the undeflected state (see Figure 5).

The undeflated measurements of the tires are as follows:

	Mud & Snow Tire	NDCC Tire
Maximum Width	7.5	7.5
Width of contact area	6.5	See Fig. 5

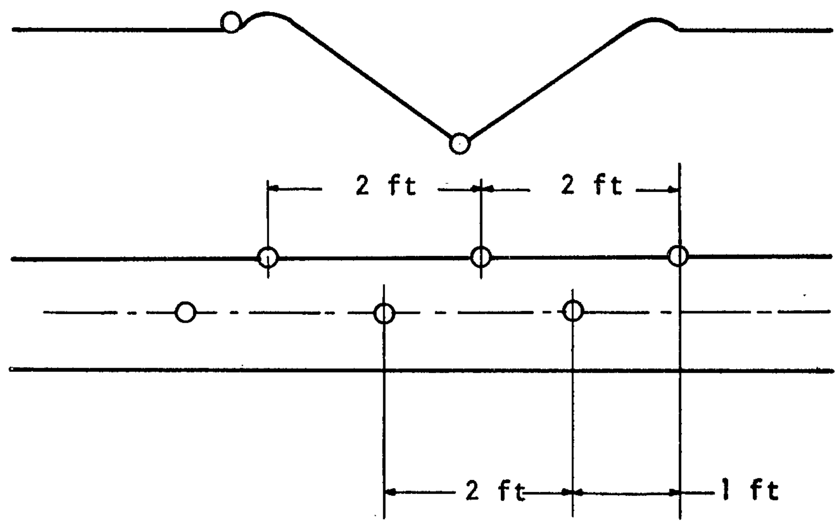

FIGURE 1. LOCATION OF CONE PENETRATION MEASUREMENTS

TABLE I

Soil Measurements

	Before Wheel Passage			After Wheel Passage					
				Bottom of Rut			Side of Rut		
Depth	3"	6"	9"	3"	6"	9"	3"	6"	9"
Cone Index Gradient-G psi/in	2.7	3.0	4.0	6.4	6.7	7.9	3.3	4.9	5.6
Standard Deviation-S psi/in	.3	.4	.2	1.2	1.0	.8	.2	.3	.3

K_c	0.0
K_φ	5.25
n	1.15

Table IIa

FOOTPRINT DIMENSIONS

		Snow Tire Load lbs				NDCC Tire Load lbs			
		900	800	700	600	900	800	700	600
15 psi	b	6-3/8	6-1/8	6-3/8	6-3/8	4-7/16	4-3/8	4-3/16	4-1/16
	ℓ	8-15/16	7-1/2	7-1/16	7	9-1/8	8-5/16	8-3/16	7-3/8
25 psi	ℓ	6-1/8	5-5/8	5-1/16	4-9/16	4-1/4	4	3-11/16	3-1/2
	ℓ	6-1/2	6-1/4	6-1/4	5-3/4	8-1/4	7-5/16	7	6-5/16

Table IIb

GROSS AREA OF FOOTPRINT $b \times \ell$ [in^2]
(to the nearest 1/2)

	Snow Tire Load (lbs)				NDCC Tire Load (lbs)			
	900	800	700	600	900	800	700	600
15 psi	57.	46.0	45.0	44.5	40.5	36.5	34.0	30.0
25 psi	40.	35.	31.5	26.	35.0	29.0	26.0	22.0

Table IIc

GROUND NOMINAL PRESSURE P = W/A (Rounded off to nearest .1)

	Snow Tire Load				NDCC Tire Load			
	900	800	700	600	900	800	700	600
15 psi	15.8	17.4	15.5	13.5	22.2	21.9	20.6	20.0
25 psi	22.5	22.0	22.2	23.1	25.7	27.6	26.9	27.3

Table IId

DEFLECTION [in] VERSUS LOAD

Pressure psi	Snow Tire Load [lbs]				NDCC Tire Load [lbs]			
	900	800	700	600	900	800	700	600
15	1.15	1.08	1.00	.93	1.60	1.45	1.30	1.15
25	1.00	.90	.80	.60	1.100	1.050	.950	.800

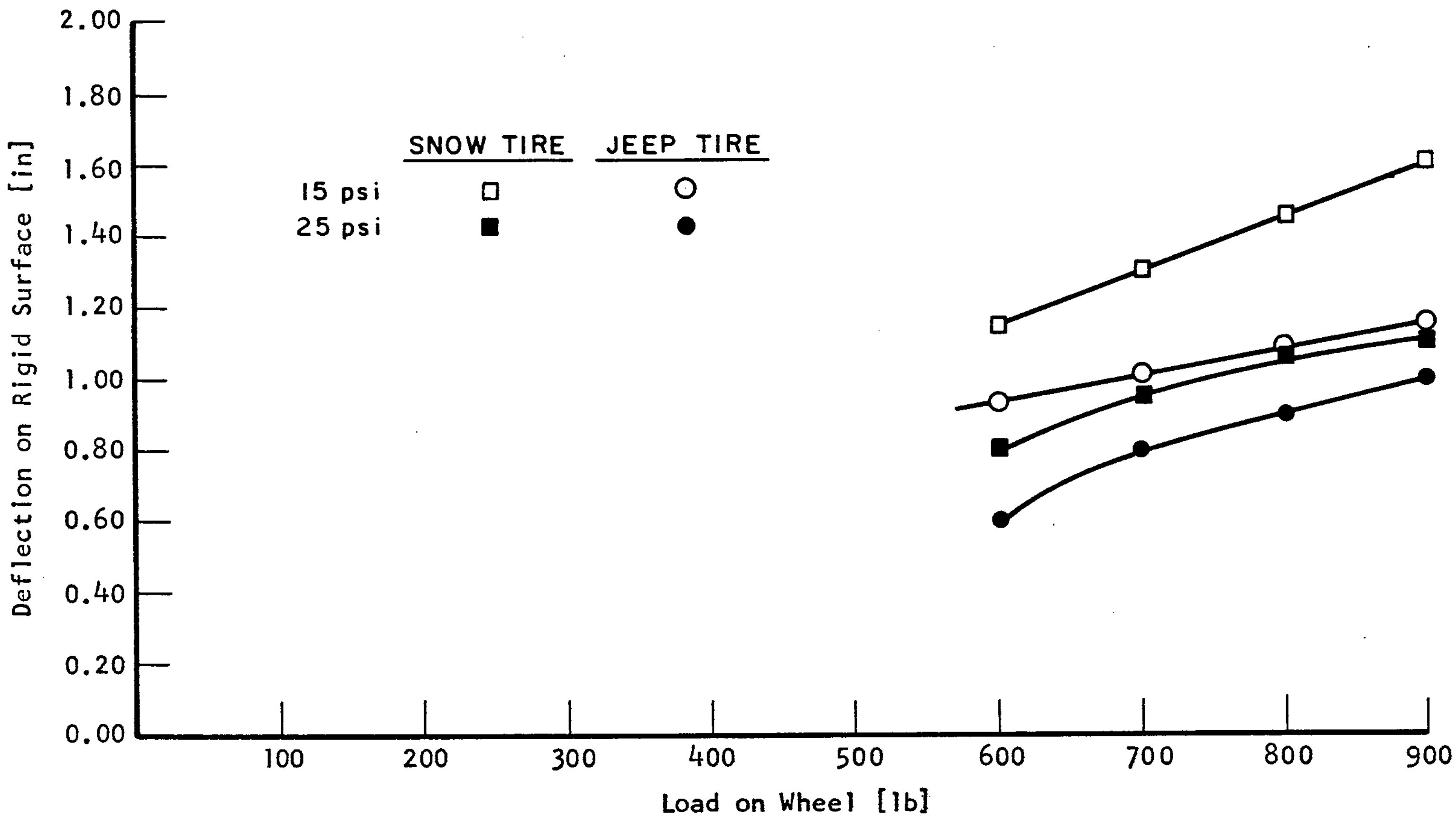

FIGURE 2. DEFLECTION VERSUS WEIGHT

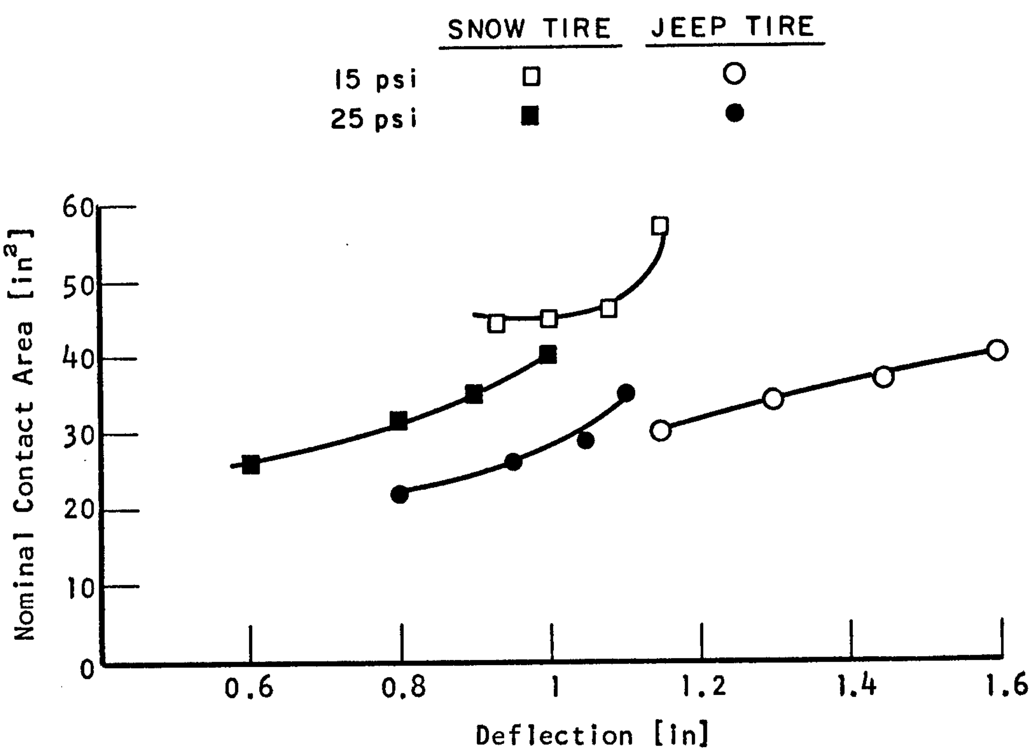

FIGURE 3. NOMINAL CONTACT AREA VERSUS DEFLECTION

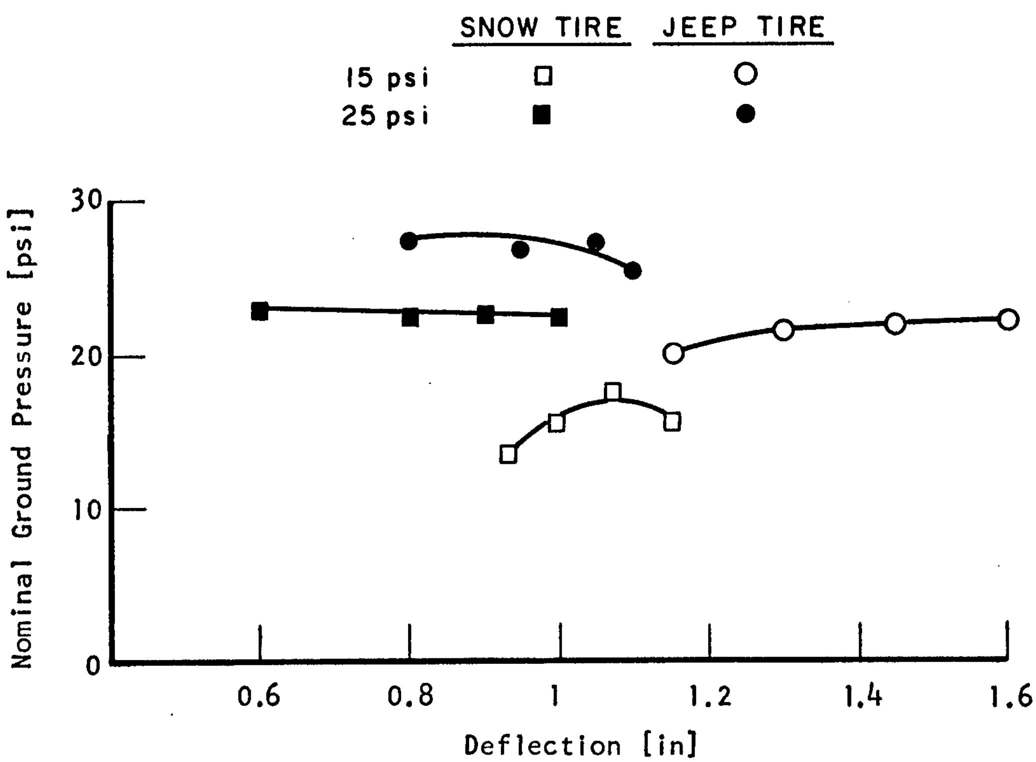

FIGURE 4. NOMINAL GROUND PRESSURE VERSUS DEFLECTION

Mud and Snow Tire

NDCC Tire

FIGURE 5. TIRE SURFACE PATTERN AND SHAPE

C. Towed Wheel Tests

Although the towed wheel test data do appear also in the next section they are handled separately here in order to accentuate the differences between the tires. From Table III it is evident that no significant difference in the drawbar pull (towed force) can be distinguished from the data. The increase from 15 psi to 25 psi does seem to have a small influence at the higher load, but not at the lower load. More tests at higher dead loads are needed to draw definite conclusions.

An interesting phenomenon observed during these tests is the increase in slip with increased weight for the snow tire, whereas the opposite appears to occur for the NDCC tire. This could very well be a result of the tire surface configuration, since it occurs at both pressure levels. Further investigation of this phenomenon may be warranted. A possible explanation is that the flow pattern around the more square snow tire profile is impeded more at the higher sinkage whereas the rounded shape of the NDCC tire facilitates flow while at the same time the higher load gives a better contact area of the non-directional profile.

A second explanation may be in the calculation of the value for slip. For both tires, the peripheral velocity of the maximum diameter was utilized. Only a small portion of the NDCC tire is traveling at that speed.

D. Driven Wheel Tests

Driven wheel tests were run at a constant velocity for each test. The load on the wheels was 620 lb (the nominal wheel load on a 1/4-ton truck), and both tires were tested at 15 and 25 psi.

Table III

TOWED WHEEL TESTS
Preliminary Test Series

Average Carriage Velocity 16.5 fpm

	Snow Tire					Tire				
Tire Pressure	Load W (lbs)	Towed Force DBP (lbs)	Sinkage Z (in)	Slip* S	Coeff. of RR DBP/W	Load W (lbs)	Towed Force DBP (lbs)	Sinkage Z (in)	*Slip S	Coeff. of RR DBP/W
15 psi	600	-205	3.50	-21.5	-.342	600	-205	3.80	-41	.342
	700	-240	4.00	-40	-.343	700	-245	4.20	-31	.350
25 psi	600	-210	3.45	-32	-.350	600	-205	3.20	-52	.342
	700	-255	3.90	-50	-.365	700	-265	3.60	-32.5	.379

*Slip calculated form: $\dfrac{\text{Wheel Peripheral Velocity} - \text{Carriage Velocity}}{\text{Wheel Peripheral Velocity}}$

From each test trace recorded, several readings were taken and the tractive efficiency and slip were computed.

The following definitions were used in conducting the calculations:

1. $\text{Slip} = S = \dfrac{\text{Wheel Peripheral Velocity} - \text{Carriage Velocity}}{\text{Wheel Peripheral Velocity}}$

The wheel peripheral velocity was measured at the maximum <u>undeflected wheel diameter</u>.

2. $\text{Tractive Efficiency} = \eta = \dfrac{DBP \times R}{T}(1-S)$

where DBP = Drawbar pull [lb]
R = Undeflected wheel radius [in]
T = Torque input to wheel [lb.ft]

The raw data were processed on a PDP-10 computer and plotted in two ways:

1. Drawbar pull (DBP) versus slip (S)
2. Tractive Efficiency (η) versus slip (S)

The results are summarized in Figures 6, 7, 8 and 9.

V. Discussion of Results

A. Low Pressure vs High Pressure

The NDCC tire at 15 psi showed an efficiency peak at a lower slip than did the mud and snow tire, the DBP at maximum slip for both cases, however, did not differ significantly.

There did not seem to be a significant difference in the behavior of the two tires, although at higher slip values the NDCC tire would appear to perform slightly better.

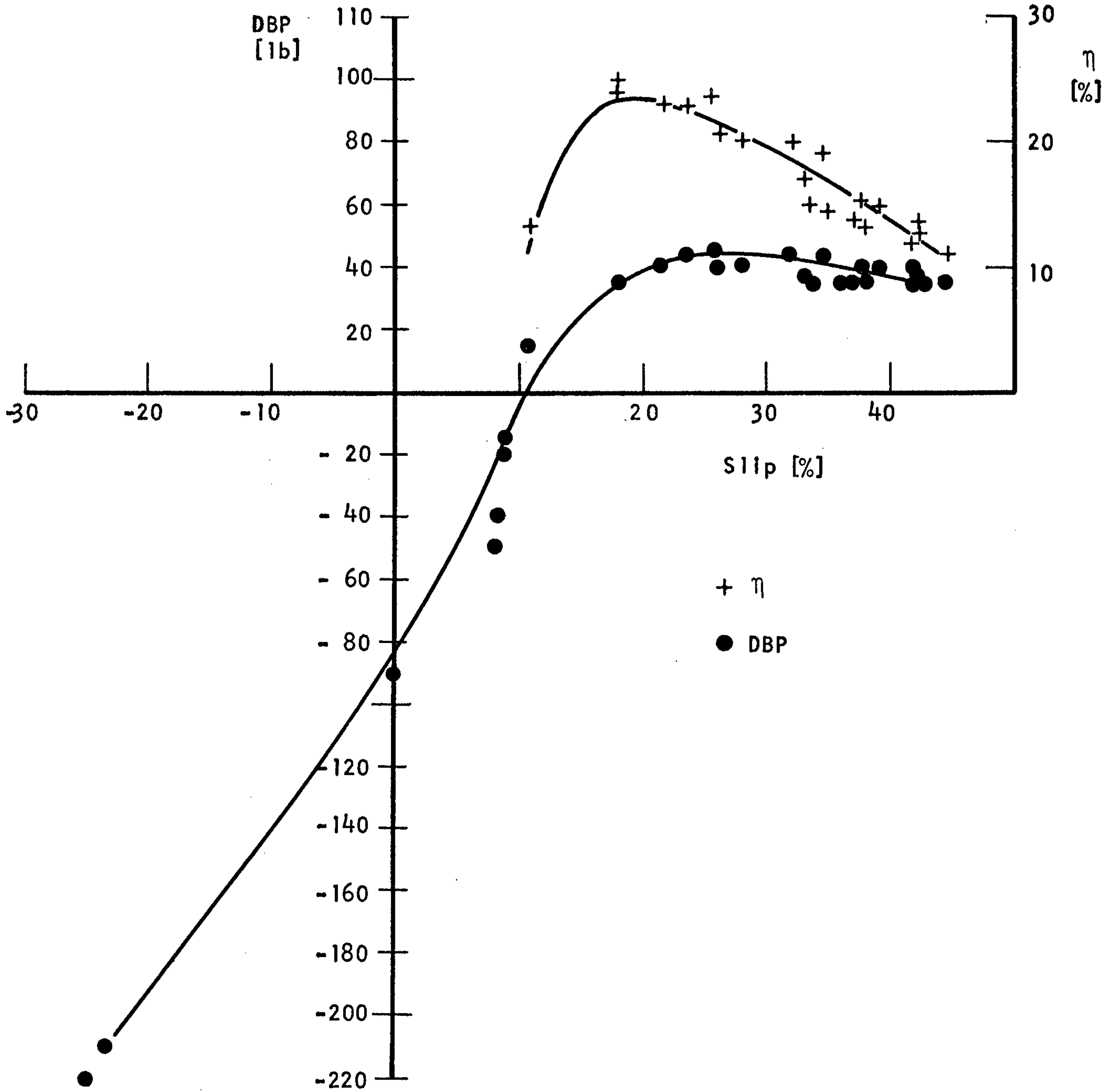

FIGURE 6. NDCC TIRE AT 15 PSI LOAD 620 LB

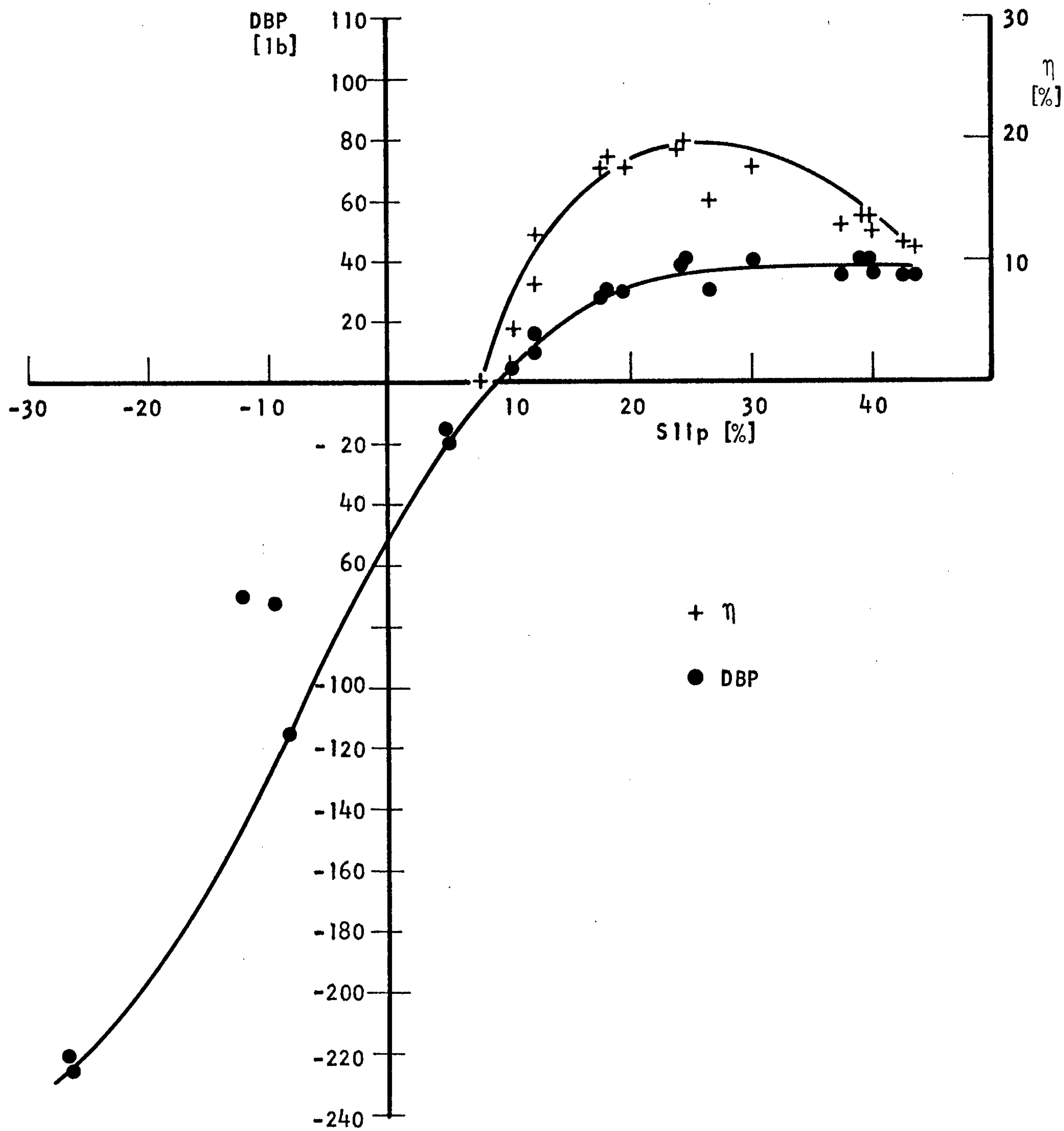

FIGURE 7. NDCC TIRE AT 25 PSI LOAD 620 LB

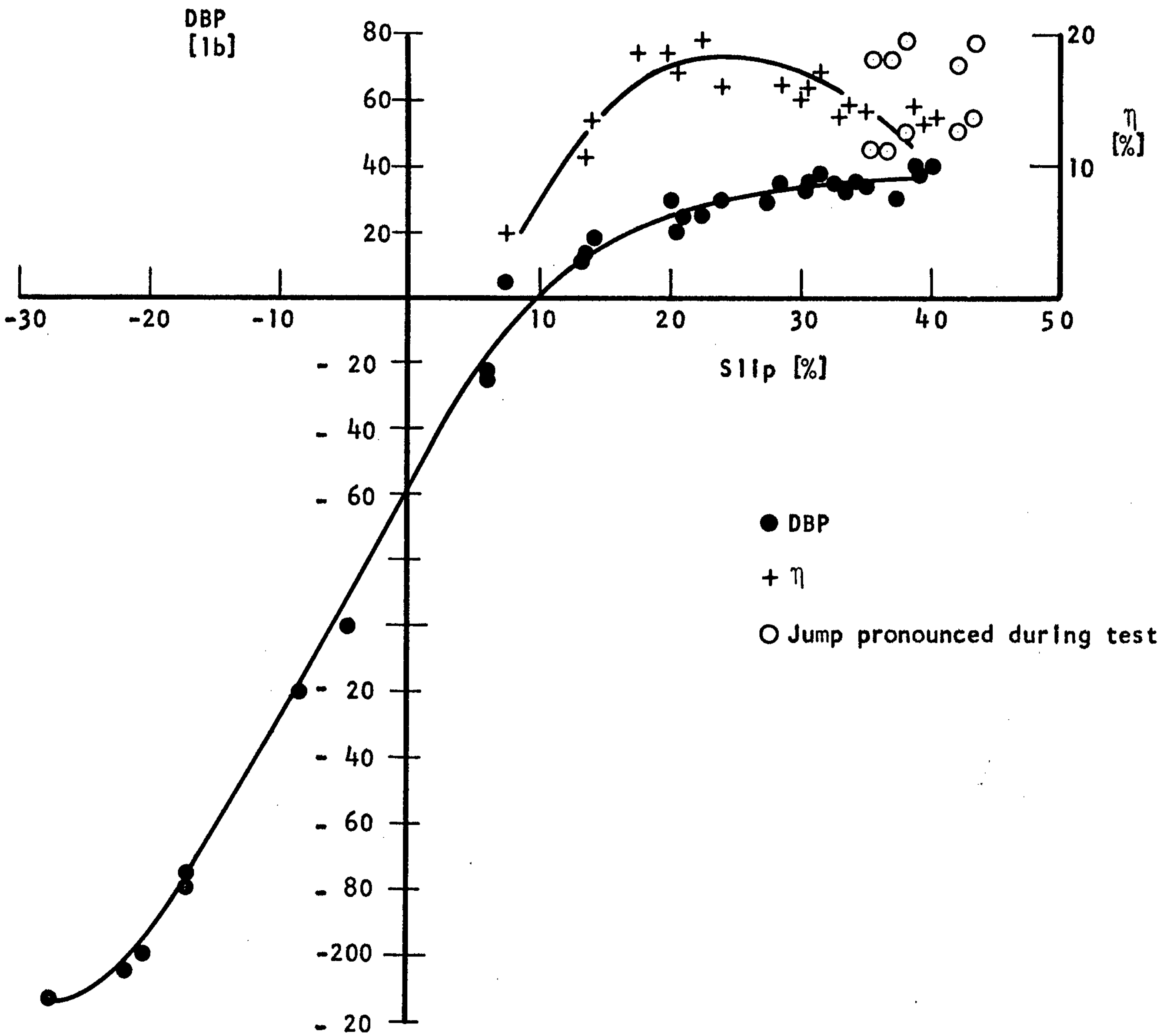

FIGURE 8. SNOW TIRE AT 15 PSI LOAD 620 LB

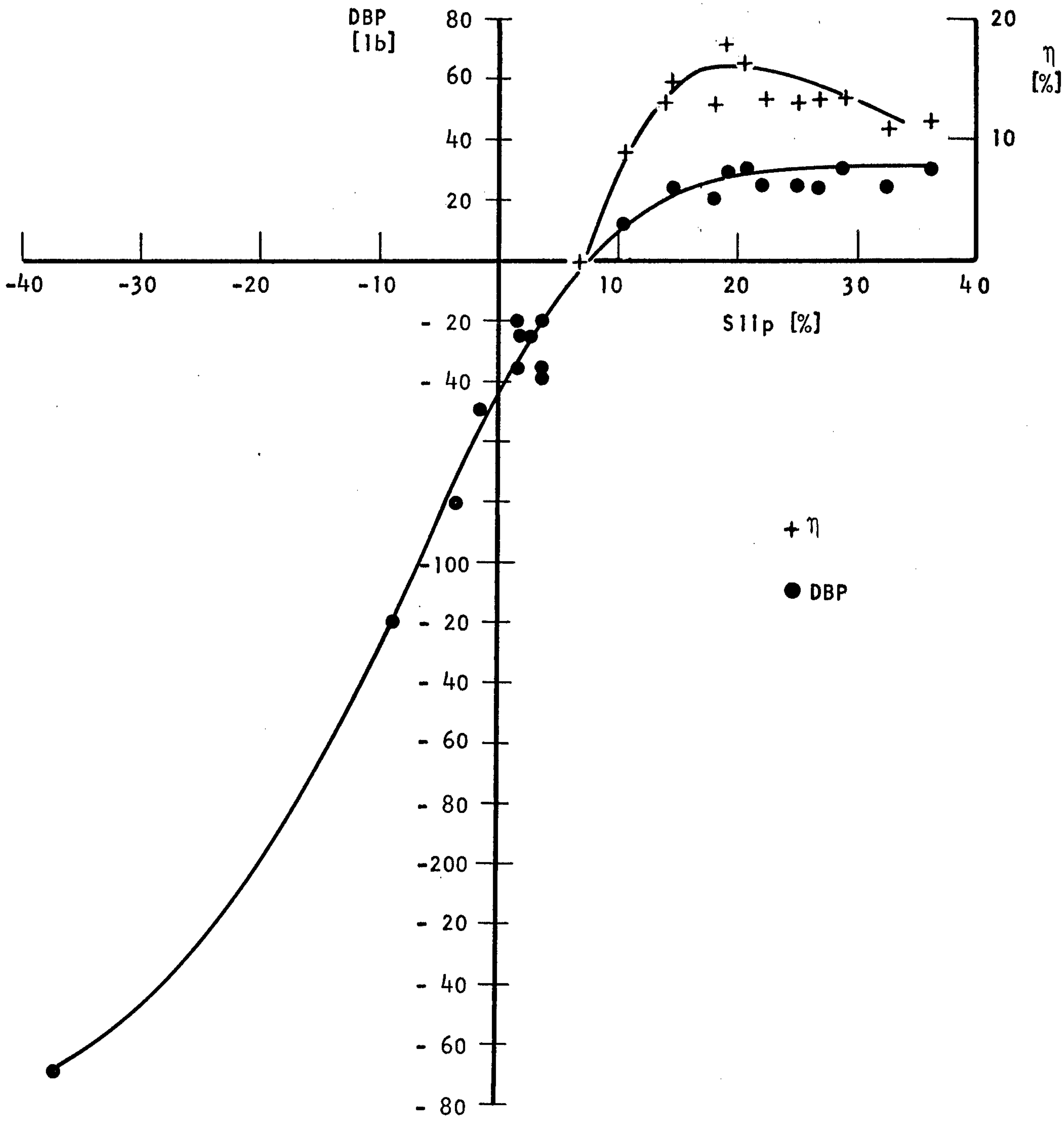

FIGURE 9. SNOW TIRE AT 25 PSI LOAD 620 LB

VI. Conclusions

The performance of the tires had to be evaluated against the fact that the soil was extremely soft. In the tests conducted the differenee between the results with the military NDCC tread and that with the civilian mud and snow tread was not large enough to warrant a definite opinion as to their overall performance.

A. At Low pressure (Figures 5 and 7)

From the available data it would seem that the NDCC tire had slightly better overall performance. In both cases zero drawbar pull appears to occur at about 10% slip.

B. At high pressure (Figures 6 and 8)

There does not seem to be a significant difference between the performances of the two tires.

VII. Discussion and Recommendations

This test series was a limited one in which only one type of tire was tested in only one soil at only one condition. The following unknowns should be evaluated for a more complete comparison.

A. Influence of tire tread patterns: Snow tires from different manufacturers or tread designers may yield different results (though this test program tends to refute this contention).

B. Influence of tire wear on performance: Whereas one tire may be better than the other when new, it could be the opposite after a certain amount of wear.

C. Soil Condition: Tests should be conducted on a variety of soil strengths and moisture content.

D. Soil Type: Tests should be conducted in clay; loam and problem soils.

E. Tire construction: Radial, bias and bias-belted construction should also be studied.

F. On-Road Performance: The whole gamut of on road performance characteristics -- braking, cornering, wear, and ride -- should be investigated to determine if any adverse effects may result from utilizing civilian tires.

The above tests should be validated by a series of full scale tests in the field.

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